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Acute effects of a hypertrophy strength training session on a subsequent steady-state endurance bout in well-trained youth kayakers

MSc in Strength and Conditioning

Manuel Matzka

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Acute effects of a hypertrophy strength training session on a subsequent steady-state endurance bout in well-trained youth kayakers

by

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This Research Project is submitted as partial fulfilment of the requirements for the degree of Master of Science, St Mary's University

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ABSTRACT

The present study examined the acute effects of a hypertrophy strength training (HST) session (4 x 8-10 repetitions at 70% 1RM) on physiological and biomechanical variables, analysed during a subsequent steady-state aerobic endurance exercise in well-trained athletes. Eleven kayakers performed two different experimental sessions in a randomized crossover design. One consisted of a HST prior to an endurance bout exercised at 55% of maximum oxygen consumption on a kayak ergometer (SE). The second session consisted of an equal endurance bout without prior exercise (E). During the endurance exercise relative $\dot{V}O_2$, blood lactate, heart-rate, respiratory exchange ratio (RER), rating perceived exertion, stroke rate, power per stroke, paddling economy and caloric unit cost were analysed between and within both conditions. No significant differences between conditions during endurance exercise for all measured physiological and biomechanical variables, except respiratory exchange ratio (RER) and lactate occurred. In the SE condition RER demonstrated significantly ($P < 0.05$) lower values compared to E during the whole endurance bout (0.85 ±0.03 compared to 0,89 ±0.04), as well as within each examined interval (0-10min: 0.85 ±0.03 vs. 0.88 ±0.04; 10-20min: 0.87 ±0.03 vs. 0.9 ±0.03; 20-30min: 0.86 ±0.03 vs. 0.89 ±0.04; 30-40min: 0.85 ±0.03 vs. 0.88 ±0.04). Lactate values (in mmol/L) prior the endurance exercise were significantly elevated in the SE condition (2.37 ±0.78 vs. 1.45 ±0.36).

HST does not seem to impair subsequent aerobic endurance exercise in well-trained athletes. Additionally, HST appears to induce optimized fat utilization during endurance exercise and aerobic endurance subsequent to HST may accelerate recovery from HST.

KEY WORDS: interference effect, exercise sequencing, concurrent training, acute hypothesis, resistance training, aerobic performance

1 INTRODUCTION

Depending on distance (1000m, 500m, 200m) race times in Olympic sprint kayaking vary between 35 seconds to 3:40 minutes in the single events for elite athletes. Aerobic contribution during the different events are approximately 82-87%, 62%-78% and 37-40% for 1000m, 500m, 200m, respectively (9,27,52). Kayaking performance highly relies on aerobic capacities, but is as well determined by a well-trained anaerobic capacity (19,22,27,36). With decreasing event distances the importance of anaerobic energy metabolism increases.

Besides the importance of aerobic and anaerobic endurance capacities, strength and power, mostly in the upper-body musculature, are important prerequisites for successful Olympic kayakers (21). The kayaker has to propel the boat-body-system against water resistance with the relatively small upper-body muscles and therefore the strength and power demands on this musculature are quite high (14). During the stroke phase the latissimus dorsi and the trunk rotators act as prime movers (49). Most common exercises in strength training protocols for kayaking are prone bench pull, chin-up and bench press (12,20,49). High strength values in these exercises built the basis for successful kayaking performances (35).

Conclusively, to enhance sprint kayaking performance the simultaneous training of strength and endurance abilities is crucial (20). The simultaneous development of strength and endurance abilities is called concurrent training (CT) and has been proven to enhance performance in endurance athletes in several studies (19,21,22,32,46).

However, concurrently training for endurance and strength in one session seems to have negative acute effects onto strength training (ST) performance if endurance exercise is preceding (1,29,38,42,47). Reed et al. (42) found a 45 minutes lasting low-intensity (75% maximum heart-rate = HR_{max}) cycle-ergometer bout to diminish subsequent back squat (6 sets to failure at 80% of one repetition maximum = 1RM) performance (42). A study by Tan et al. (29) found similar effects of an aerobic endurance bout at 70% HR_{max} on an elliptical machine prior to three sets to failure at 75% 1RM in the back squat. Acute muscular fatigue as a result of local metabolic and or neuromuscular stress is believed to be a main reason for the acute detriments in strength performance subsequent to endurance bouts and the effects seem to be limited to the prior exercised musculature (29,42,47). These acute reductions in total volume due to residual fatigue from endurance training (ET) may further lead to impairments in long-term strength development. The acute negative effects of an ET onto strength performance seem to disappear, when enough rest (at least 8 hours) is given prior the ST (34,47). Therefore, when aiming to improve strength training performance, acutely sequencing strength prior endurance bouts or, if not possible, separating both training modalities by at least 8 hours, may lead to superior results.

Study findings on the reverse exercise order are equivocal. Investigations on the acute effects of sequencing ST prior to ET found detrimental (3,11,13,31) as well as no effects on subsequent endurance performance and physiological variables (37,46,50). A study by Kang et al. (31) examined the acute effects of both, a high intensity (90% 8RM) and a low intensity (60% 8RM) ST on physiological variables during subsequent steady-state endurance exercise (50% of peak oxygen consumption = $\dot{V}O_{2peak}$). Compared to a control group, which only did the endurance bout with no prior exercise, they found increases in $\dot{V}O_2$, HR and expired ventilation, while RER decreased. The effects were greater when the high intensity resistance training preceded. As ET generally aims for improvements in the reliance on fat metabolism during exercise, the authors recommended sequencing ST prior endurance exercise, despite the fact that also $\dot{V}O_2$ and HR were elevated. Conçeicão et al. (11) examined performance and physiological variables in a time to exhaustion (TTE) trial at the second ventilatory threshold subsequent to two different resistance training protocols (Squat: 6x8 at 75% 1RM; or countermovement jump: 6x8 with bodyweight). They found significant decreases in TTE. But in contrast to the aforementioned study these performance detriments were not accompanied by changes in VO_2 or HR compared to the control group. In another study (46) two different strength-training protocols (leg press: 5x5RM or 2x15RM) didn't show any effects on exercise performance or physiological measures ($\dot{V}O_2$, HR, lactate) during two different 5km running-protocols (continuous run at average velocity of the first and second ventilatory thresholds or intermittently at velocity of $\dot{V}O_{2max}$).

Interpretation of the studies on acute sequencing of strength and endurance training for kayakers is difficult as they differed in the implemented endurance and strength training regimes and therefore probably lead to different results. For example, intensity and duration for both strength and endurance training have been found to have an impact on performance and physiological measures (33). Additionally, utilised rest periods between the training modalities differed between the studies (5-20min) and are a potential reason for the different outcomes. Short rest periods (<10mins) may not be sufficient to restore muscle metabolic status towards baseline and therefore lead to performance detriments in subsequent endurance bouts. Longer rest periods (>10mins) can have a potentiating effect on subsequent endurance performance variables and physiological measures (4). This has been shown to induce performance increases when severe to heavy intensity endurance bouts precede the main endurance exercise (4,7). Furthermore, the implemented training modalities did not reflect common training sessions of kayakers. For example, ST mostly consisted of only one exercise, whereas regimen in kayaking typically consists of 4 to 6 multi-joint exercises (21). Additionally, the examined participants were almost exclusively sedentary or recreational athletes. As evidence suggests that performance level and training status have an impact on the effects of CT (18), it is difficult to draw conclusions for well-trained athletes. In addition, the above-mentioned studies exclusively examined lower-body endurance exercises. As there are differences in muscle mass distribution of muscle fibre-types in the upper-body, effects may be different in sport-specific strength and endurance training of kayakers. Till today, only one study examined a CT protocol with elite kayakers aiming to diminish the residual fatigue of endurance training on the strength development. A 12-week training intervention in elite-kayakers by García-Pallarés et al. (22) sequenced the strength prior to endurance sessions or, if not possible, seperated them by at least 8 hours and found performance increases in both strength and endurance parameters. However, as the study did not investigate the reverse exercise order it is impossible to evalute, if the improvements in strength and endurance performance possibly differ from the opposite sequencing. Additionally, no acute effects of the exercise sequencing were investigated.

In summary, evidence suggests that performing ST prior to ET is favourable when aiming for reduced residual fatigue in ST sessions, but it remains unclear whether this session-order acutely has detrimental effects on the subsequent ET. Especially with regard to training practices in kayaking it is difficult to draw conclusions and make recommendations for best practice.

Therefore the current study aimed to examine the acute effects of a strength training on biomechanical and physiological variables during an aerobic endurance bout in a common CT session of well-trained kayakers. As the study had to be conducted in winter, during the general prepatation phase (GPP), we chose to examine a common session for this period, because the athletes were used to these training modalities. During the GPP the development of basic aerobic endurance and structural hypertrophy build main training emphases of kayakers (15). In kayaking, the aerobic endurance is mainly developed by long slow distance training (LSDT) at an intensity of about 50 to 70% HR_{max} for a single repetition with a duration of 40 to 60 minutes (15). Therefore, the aim of the present study was to examine the acute effect of hypertrophy strength training (HST) on physiological and biomechanical variables during a steady-state LSDT session on a kayak ergometer in well-trained kayakers. This was compared to a similar endurance workout, which was not preceded by any exercise.

Based on earlier findings (11,37,46,50) it was hypothesised that sequencing HST prior to an aerobic endurance bout would not impair the endurance performance in well-trained kayakers. Furthermore, compared to ET-only it was supposed lactate accumulation would be elevated prior and during the first minutes of the endurance bout subsequent to ST.

2 METHODS

2.1 Experimental Approach to the Problem

The objective of the study was to determine if HST compromises subsequent steady-state aerobic endurance performance. In order to examine this each subject underwent two different training regimes. One regime consisted of a HST performed prior to a LSDT on an air-braked kayak ergometer with 20 minutes rest in-between (SE). The other regime included the same endurance session as performed in the first regime but without any preceding exercise (E).

2.2 Participants

Eleven well-trained kayakers (10 female/1 male) were recruited from a regional performance base-camp in western Germany. Participant characteristics are highlighted in table 1. The Ethics Sub-Committee of St Mary's University Twickenham London approved the study design. Participants were informed about risks and benefits of the investigation prior signing the participant consent form. Furthermore, parents of adolescent participants got informed and had to sign an additional consent form prior the investigation.

Table 1. Subject Characteristics

	Mean	**SD (+/-)**
Age	16.00	1.15
Body height (m)	1.70	0.07
Body weight (kg)	60.10	8.18
Body-Mass-Index	19.09	6.14
Body fat (%)	22.45	4.74
Arm span width (cm)	171.42	7.50
Sitting height (cm)	86.95	4.24
Training days / week (d)	6.00	0.00
Weekly training duration (h)	9.32	0.96

2.3 Procedures

The study followed a randomised crossover design. Each participant performed the SE and E session in a randomised fashion (Figure 3). They were required to visit the laboratory on four occasions. Participants were asked not to do any physical exercise 48 hours prior to the experimental sessions and to stick to their ordinary diet. The first session consisted of anthropometric measurements (see below), completion of a questionnaire regarding the training history and a one repetition maximum (1RM) test to determine the loads for the hypertrophy strength-training session. Exercises were bench pull (BPU), bench press (BPR), latissimus pull-down (LP) and shoulder press (SP). These exercises are typically used in strength training routines for kayaking and train the prime movers of the kayak stroke (22,44,49). Participants had at least two years of weight training experience in these exercises. BPU, BPR and SP were performed using free weights. LP was performed on a latissimus machine (MegaTec/IFS Vertriebs GmbH, Germany). Movement velocity was prescribed as controlled and moderate for the eccentric part of the lift (2-3 seconds) and maximally explosive for the concentric part. An approximately one second lasting isometric hold had to be performed at the turning point after the eccentric phase. The BPU was executed while lying prone on a flat bench with the feed pushed against a footrest at the end of the bench for stabilization. During BPR participants lay on a flat bench with shoulders and buttocks stable on the bench and feed flat on the floor. SP was performed from a standing position. The LP was executed from a sitting position with the feed flat on the floor. Each lift had to be executed in the full range of motion. On the second occasion, 48 hours later, $\dot{V}O_{2max}$ was defined using an incremental test on a kayak ergometer (WEBA sport kayak ergometer; WEBA Sport and med. Article GmbH, Austria) to determine the intensity for the endurance bouts (see below). One week later, the first experimental session started in a randomised fashion, followed by the residual session one week later. Sessions were conducted in the same daily timeframe (±1.5 hours) to reduce influence of daytime effects. The study was processed in February 2016, which is situated in the general preparation phase of kayakers, where LSDT kayaking and HST are main training emphases. Therefore, all participants were used to the exercises, intensities and modes performed and no additional familiarisation was needed.

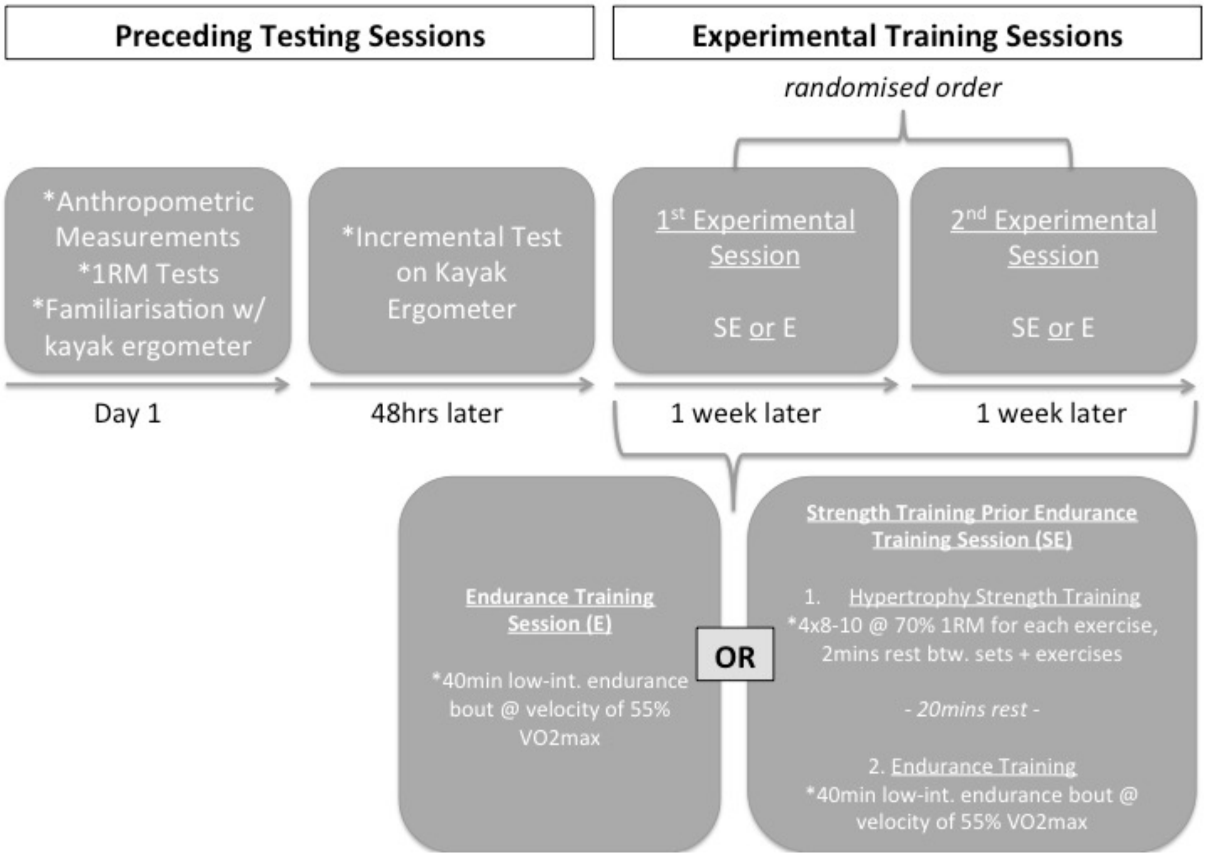

Figure 1. Study design overview.

Anthropometric Measurement

Body mass, –height, arm span width and sitting height (while sitting on the ergometer: from the seat to the top of the head) were assessed using a commercial measuring tape. Body composition (bioelectrical impedance analysis via Tanita MC-980MA; Tanita Europe B.V./Netherlands) was assessed and Body-Mass-Index was calculated as body mass in kilograms divided by height in meters squared (BMI = kg / m^2).

One Repetition Maximum Test

A standardised whole body warm-up (10 minutes) consisting of 5 minutes low-intensity cycling followed by two sets of 30 repetitions for four upper-body / shoulder exercises (band-pull-apart, scapula push-up, banded shoulder dislocation, Y's and W's) preceded the strength testing. The 1RM testing followed the guidelines provided by Baechle and Earle (2). Warm-up sets included 10 repetitions at about 50% of the estimated 1RM and a set of 5 repetitions at 75%-1RM with one-minute rest. Two minutes rest were given before performing a circa-maximal set of 3 repetitions at 90%-1RM. After four minutes rest the first 1RM attempt was performed. Up to three more attempts were allowed to reach the 1RM. Weight increases between attempts were 2.5kg to 5kg. Attempts were valid when proper technique and full range of motion in each exercise were realised. Exercises were explained and supervised by an experienced strength and kayak coach. Exercise order was as follows: BPU, BPR, LP, SP. Pulling and pressing movements were alternated to allow for more recovery in the main muscle groups used in the respective movements. Warm-up weights were determined from 1RM values from a previous 1RM test of the participants. Test results can be found in table 2.

Incremental Test.

An incremental test to exhaustion on a kayak ergometer was conducted to determine $\dot{V}O_{2max}$ for each participant. The test protocol was based on the one used by García-Pallarés et al. (22). After a 5-minute warm-up at 9 km/h the incremental test started at 10 km/h with 0.5 km/h increments each minute until volitional exhaustion. Kayakers were allowed to adjust their stroke rate as needed. They were encouraged to accomplish as many increments as possible until volitional exhaustion. Heart rate was monitored using a Polar HR-monitor (Polar Electro Oy, Finland). Gas analysis was realised with a portable spiroergometry (METAMAX 3B, Cortex Biophysik GmbH, Germany). $\dot{V}O_{2max}$ was determined as the mean

$\dot{V}O_2$ of the highest 15-second $\dot{V}O_2$-interval towards the end of the incremental test. Additionally, whole blood samples from the participants' earlobe were taken immediately prior and subsequent to the test, as well as 1, 3, 5 and 7 minutes post using a lactate-scout+ (EFK Diagnostics / SensLab GmbH, Germany). Absolute and relative $\dot{V}O_{2max}$, maximum HR (HR_{max}), peak lactate, peak paddle speed at $\dot{V}O_{2max}$ and peak stroke rate at $\dot{V}O_{2max}$ was determined. Test results are highlighted in table 3.

Hypertrophy Strength Training Session.

The warm-up was the same as used for the 1RM test. The protocol followed recommendations by García-Pallarés and Izquierdo (21). Exercises were implemented in a stationary fashion using the same equipment as in the 1RM test and in the following order: BPU, BPR, LP, SP. Each exercise was performed for four sets with eight to ten repetitions at an intensity of 70%-1RM. Rest between sets and exercises were set to two minutes.

Table 2. 1RM test data

Exercise	**Mean**	**SD (+/-)**
Bench Pull (kg)	56.88	12.21
Bench Press (kg)	46.25	10.43
Latissimus Pull (kg)	72.92	11.31
Shoulder Press (kg)	31.88	4.69

Table 3. Incremental test data

Variable	Mean	SD (+/-)
Absolute $\dot{V}O_{2max}$ (L/min)	2.67	0.31
Relative $\dot{V}O_{2max}$ (mL/min/kg)	44.42	4.55
Lactate peak (mmol/L)	8.02	1.84
HR_{max} (bpm)	192	8
Peak Paddle Speed (km/h)	12.20	0.56
Peak Stroke Rate (spm)	112	9

Long-Slow Distance Training Session

The LSDT session was a steady-state endurance session on the same kayak ergometer as used in the incremental test. Sessions lasted 40 minutes and intensity was set to a speed of about 55% $\dot{V}O_{2max}$. According to Baechle and Earle (2) this velocity equals about 70% HR_{max}, which is a common intensity for LSDT in kayaking (16). A five-minute warm-up on the ergometer at a speed of 7-8 km/h preceded the bout. In the SE condition 20 minutes rest after ST were implemented. Using the same equipment as in the incremental test, $\dot{V}O_2$ was analysed during the whole endurance session, which reflects a typical time frame that athletes need for change and to start the following exercise. Furthermore, whole blood samples from the participants' earlobe were taken immediately prior and at minute 10, 20, 30 and 40 of the endurance session. The following variables were analysed: Relative $\dot{V}O_2$, blood lactate, HR, respiratory exchange ratio (RER), rating perceived exertion (RPE), stroke rate (SR), power per stroke (PSTR), paddling economy (ECO) and caloric unit cost (CUC). ECO was determined according to a calculation by Peeling et al. (39) who defined the economy as the relative oxygen cost of distance travelled (mL/kg/km). CUC (in kcal/kg/km) was calculated according to Fletcher et al. (CUC $=\dot{V}O_2$ * caloric equivalent * s^{-1} * BM^{-1} * K), where $\dot{V}O_2$ is measured in L/min, caloric equivalent is in kcal/L, speed (s) is in m/min, body mass (BM) is in kg, and K is 1000 m/km (16).

2.4 Statistical Analysis

The statistical Package for Social Science (Version 21; IBM Corp., Armonk, NY) was utilised for all statistical analysis. Descriptive statistics were determined using standard statistical methods. Statistical significance was accepted at a value of $p \leq 0.05$. Key dependent variables were as follows: Relative $\dot{V}O2$, RER, HR, ECO, CUC, SR and PSTR for the whole LSDT bout, as well as for each ten minute interval (0-10min, 10-20min, 20-30min, 30-40min); lactate prior the LSDT bout and at the end of each interval; RPE immediately prior and at the end of the LSDT bout. Independent variable was the training condition (SE, E) and time intervals (TI) or time points, respectively. The Shapiro-Wilks test and Levene's test for equality in variances were used for all data to analyse normality and homogeneity of variances. Two-Way ANOVA (lactate, $\dot{V}O2$, SR, PSTR, ECO) was implemented for normally distributed variables to test for between- and within-condition differences in all outcome measures for the collected time points and intervals. Where significant main effects were observed, simple main effect analyses were performed and Tukey's post hoc tests were implemented to locate significant differences. For not normally distributed data (RER, HR, CUC) the Friedman test was conducted to assess for differences in TI between conditions. Where significant differences were observed, a post hoc analysis via Wilcoxon Signed-Rank test was conducted to locate significant differences. Additionally, Wilcoxon Signed-Rank test was utilized for the same variables to analyse for any differences between TI within conditions. Furthermore, differences in mean values for every dependent variable during the total endurance bout were analysed with paired-sample t-test ($\dot{V}O2$, SR, PSTR, ECO) for normally distributed data and with Wilcoxon Signed-Rank test for not normally distributed data (RER, HR, CUC). Effect sizes were classified using the scale by Cohen (10), where 0.0-0.41 equal a small, 0.41-0.70 equal a moderate and 0.70 or greater represent a large effect size and reported as follows: d = cohens' d value, *effect size*.

3 RESULTS

The results are highlighted in tables 4 ($\dot{V}O_2$, SR, PSTR, ECO, CUC, RER, HR) 5 (lactate) and 6 (RPE). No significant differences between conditions for $\dot{V}O_2$ (d = 0.07, *small*), SR (d = 0.03, *small*), PSTR (d = 0.14, *small*) and ECO (d = 0.11, *small*) were found. Additionally, Wilcoxon Signed-Rank test resulted in no significant differences between groups for the whole 40-minute bouts in CUC (d = 0.12) and HR (d = 0.19, *small*). Values of RER were the only that highlighted significance in differences for the total exercise bout (Z = -2.40, p = 0.02, d = 0.51, *medium*).

Factorial ANOVA revealed no effects for $\dot{V}O_2$, SR, PSTR, ECO with respect to condition ($\dot{V}O_2$: d = 0.35, *small*; SR: d = 0.35, *small*; PSTR: d = .69, *medium*; ECO: d = 0.51, *medium*), TI ($\dot{V}O_2$: d = 0.55, *medium*; SR: d = 0.74, *large*; PSTR: d = .59, *medium*; ECO: d = 0.35, *small*) and interaction of condition and TI ($\dot{V}O_2$: d = 0.35, *small*; SR: d = 0.35, *small*; PSTR: d = .59, *medium*; ECO: d = 0.46, *medium*). Blood lactate analysis revealed that the main effect for condition was significant, F(1, 100) = 8,86, p < 0.01 (d = 1.31, *large*), as was the main effect for time point, F(4, 100) = 18.58, p < .001 (d = 4.98, *large*). The interaction was also significant, F(4, 100) = 4.64, p < .01 (d = 1.78, *large*). Tukey's post hoc test of the interaction revealed that only the SE_{pre} significantly differed with higher lactate values compared to every other interaction with p < 0.001 (d = 2.0).

The Friedman test on RER found significant differences in TI between (Chi-square = 35.05, p < 0.001) conditions. Post hoc analysis resulted in significant differences for each interval (SE vs. E: 0-10min: Z = -2.23, p = 0.03, d = 0.48, *medium*; 10-20min: Z = -2.36, p = 0.02, d = 0.5, *medium*; 20-30min: Z = -2.25, p = 0.02, d = 0.48, *medium*; 30-40min: Z = -2.77, p = 0.01, d = 0.59, *medium*). Within condition analysis revealed significant differences in the SE condition for 0-10min vs. 10-20min (Z = -2.32, p = 0.02, d = 0.5, *medium*) 10-20min vs. 30-40min (Z = -2.84, p < 0.01, d = 0.61, *medium*), 20-30min vs. 30-40min (Z = -2.40, p = 0.02, d = 0.51, *medium*) and in the E condition for 0-10min vs. 10-20min (Z = -2.46, p = 0.01, d = 0.52, *medium*), 10-20min vs. 20-30min (Z = -2.60, p = 0.01, p = 0.55, *medium*), 10-20min vs. 30-40min (Z = -2.85, p = 0.01, d = 0.61, *medium*) and 20-30min vs. 30-40min (Z = -2.46, p = 0.01, d = 0.52, *medium*). No statistical differences in the SE condition were found for TIs 0-10min vs. 20-30min (d = 0.37, *small*), 0-10min vs. 30-40min (d = 0.00, *small*), 10-20min vs. 20-30min (d = 0.41, *medium*) and in the E condition for TIs 0-10min vs. 20-30min (d = 0.22, *small*) and 0-10min vs. 30-40min (d = 0.06, *small*). For CUC Friedman test resulted in no significant differences in time intervals when comparing conditions (d = 1.53, *large*). Within condition analysis resulted only in a significant difference between TI 0-10min and 30-40min within the SE condition (Z = -2.01, p = 0.04, d = 0.43, *medium*), but not in any of the other combinations (0-10min vs. 10-20min: d = 0.36, *small*; 0-10min vs. 20-30min: d = 0.39, *small*; 10-20min vs. 20-30min: d = 0.26, *small*; 10-20min vs. 30-40min: d = 0.34, *small*; 20-30min vs. 30-40min: d = 0.30, *small*). No significance was found for the E condition (0-10min vs. 10-20min: d = 0.06, *small*;0-10min vs. 20-30min: d = 0.19, *small*; 0-10min vs. 30-40min: d = 0.19, *small*; 10-20min vs. 20-30min: d = 0.16, *small*; 10-20min vs. 30-40min: d = 0.15, *small*; 20-30min vs. 30-40min: d = 0.03, *small*). Furthermore, no significance in differences between TIs were found for HR between conditions (d = 0.68, *medium*) and within the SE (0-10min vs. 10-20min: d = 0.02, *small*;0-10min vs. 20-30min: d = 0.04, *small*; 0-10min vs. 30-40min: d = 0.06, *small*; 10-20min vs. 20-30min: d = 0.06, *small*; 10-20min vs. 30-40min: d = 0.04, *small*; 20-30min vs. 30-40min: d = 0.13, *small*) and E condition (0-10min vs. 10-20min: d = 0.30, *small*;0-10min vs. 20-30min: d = 0.18, *small*; 0-10min vs. 30-40min: d = 0.13, *small*; 10-20min vs. 20-30min: d = 0.11, *small*; 10-20min vs. 30-40min: d = 0.02, *small*; 20-30min vs. 30-40min: d = 0.06, *small*).

Finally, significant differences for RPE (table 6) were found prior the exercise bout between conditions (Z = -2.10, p = 0.04, d = 0.45, *medium*) but not subsequent (d = 0.17, *small*).

Table 4. Physiological and biomechanical measures during the whole endurance bouts and for each 10min interval.

		time interval				
Variable	**Condition**	**0-40min**	**0-10min**	**10-20min**	**20-30min**	**30-40min**
$\dot{V}O_2$	SE	23.97 ± 3.28	24.46 ± 3.33	23.9 ± 3.05	23.72 ± 3.28	23.55 ± 3.64
(mL/min/kg)	E	23.66 ± 3.38	23.93 ± 3.35	23.6 ± 3.31	23.51 ± 3.38	23.61 ± 3.66
HR	SE	149.86 ± 9.30	149.11 ± 9.92	149.44 ± 9.62	149.59 ± 9.52	149.39 ± 9.23
(bpm)	E	151.97 ± 6.45	150.59 ± 7.46	152.37 ± 6.67	152.00 ± 6.68	152.90 ± 8.34
RER	SE	0.85 ± 0.03 *	0.85 ± 0.03 *#	0.87 ± 0.03 *$	0.86 ± 0.03 *$	0.85 ± 0.03 *
	E	0.89 ± 0.04	0.88 ± 0.04 #	0.9 ± 0.03	0.89 ± 0.04 $#	0.88 ± 0.04 #
ECO	SE	23.91 ± 3.28	24.46 ± 3.33	23.9 ± 3.05	23.72 ± 3.28	23.55 ± 3.64
(mL/kg/km)	E	23.66 ± 3.38	23.93 ± 3.35	23.6 ± 3.31	23.51 ± 3.38	23.61 ± 3.66
CUC	SE	0.83 ± 0.10	0.84 ± 0.10 $	0.83 ± 0.09	0.82 ± 0.09	0.81 ± 0.10
(kcal/kg/km)	E	0.83 ± 0.11	0.83 ± 0.10	0.83 ± 0.11	0.82 ± 0.11	0.82 ± 0.11
SR	SE	59.63 ± 4.99	59.13 ± 5.06	59.31 ± 5.06	59.87 ± 5.08	60.23 ± 5.51
(spm)	E	59.5 ± 4.87	58.95 ± 4.69	58.6 ± 4.09	59.51 ± 5.03	60.54 ± 5.63
PSTR	SE	45.51 ± 5.51	45.77 ± 8.08	45.69 ± 7.64	45.11 ± 7.37	45.53 ± 7.31
(W)	E	44.38 ± 8.20	45.23 ± 8.42	41.78 ± 8.61	43.72 ± 8.18	44.61 ± 8.18

*Note. *= Values significantly differed from the E condition; #= significantly differed from "10-20min interval" in same condition; $= significantly differed from "30-40min interval" in same condition; (p= 0.05)*

Table 5. Blood lactate values (in mmol/L) at the different time points measured.

	time point				
Condition	**pre**	**10 min**	**20 min**	**30 min**	**40 min**
SE	2.37 ± 0.78*	1.38 ± 0.33	1.16 ± 0.30	0.95 ± 0.30	1.01 ± 0.37
E	1.45 ± 0.36	1.2 ± 0.42	1.06 ± 0.31	1.01 ± 0.33	0.95 ± 0.31

*Note. * = Values significantly differed from the E condition (p = 0.05).*

Table 6. Rating perceived exertion (RPE) before and after the endurance exercise.

		time point	
Variable	**Condition**	**pre**	**post**
RPE	SE	10.36 ± 2.53*	12.09 ± 2.43
	E	8.55 ± 2.64	11.64 ± 2.99

*Note. * = Values significantly differed from the E condition (p = 0.05).*

4 DISCUSSION

To the best of the authors' knowledge, this was the first study examining the acute effects of upper-body strength training on biomechanical and physiological measures during a subsequent steady-state aerobic endurance exercises in concurrently trained kayak athletes. We hypothesised that sequencing HST prior to aerobic endurance exercise would not impair the endurance performance in well-trained kayakers. Furthermore, compared to the E condition it was supposed lactate accumulation would be elevated prior and during the first minutes of the endurance bout subsequent to HST.

The main finding of the present study was that no significant differences for $\dot{V}O_2$, HR, ECO, CUC, SR, PSTR and lactate between the E and SE condition during the endurance bout occurred, as well as for RPE values subsequent to the endurance exercise. Interestingly, these results occurred, although HST lead to metabolic stress and fatigue, as highlighted in the significantly higher values for lactate and RPE, which were determined immediately prior to the endurance bout. The findings support our hypothesis that a HST has no detrimental effects on both physiological and biomechanical performance variables during a subsequent LSDT in well-trained kayakers.

Our data corroborate with findings of previous studies examining the effect of ST on aerobic endurance sessions (46,50,51). Vilacxa Alves et al. (50) examined the effect of a whole body HST (70%1RM) on a 20-minute aerobic interval session (2-min at 40% $\dot{V}O_{2peak}$/1-min at 75% $\dot{V}O_{2peak}$) on a cycle-ergometer and found no differences in mean $\dot{V}O_2$ (50). De Souza et al. (46) also found no changes in $\dot{V}O_2$, lactate, HR and RPE during intermittent (1-min at velocity of $\dot{V}O_{2max}$/1-min rest) and continuous (average intensity of 1st and 2nd ventilatory threshold) 5-km runs subsequent to both a maximal strength (5x5RM) and a strength-endurance (2x15RM) training on the inclined leg press (46). Both studies used even higher endurance training intensities as the present investigation, but still found no detriments from the previous resistance-training bout. However, both studies used shorter endurance sessions and therefore the question remains, if longer exercise duration would have lead to changes in the physiological parameters measured. Furthermore, de Souza et al. examined strength-training protocols that only consisted of one single exercise, which does not reflect typical strength sessions in sports. Additionally, Vilacxa Alves et al. did not only found no detrimental effects of ST on endurance performance variables, but also no detrimental effects on ST performance variables when training in the reverse order and therefore stated that the order of both training modes not acutely affected each other. Unfortunately, the present study did not examine the reverse exercise order and therefore no comparisons in this direction can be made. A subsequent study that compares both exercise orders in well-trained kayakers should be an aim for future research.

Conceição et al. (11) found ambivalent results of resistance training on the subsequent endurance performance (2nd ventilatory threshold) in a TTE trial when compared to the TTE with no prior exercise. They found no significant differences in $\dot{V}O_2$ and HR during the endurance bout, but exhaustion occurred significantly earlier when resistance training preceded. They assumed that ST did not result in a sufficient exercise post oxygen consumption (EPOC) to have an impact on average $\dot{V}O_2$ in the subsequent endurance bout. Decrements in TTE were likely caused by the concomitant reductions in maximal strength and rate of force development measured following the resistance bout. According to the authors, these decreases may have reflected type II fibre fatigue, which would have decreased the amount of contribution of these fibers to performance. In contrast, Kang et al. (31) used even lower aerobic endurance intensities (50%$\dot{V}O_{2max}$) during an endurance cycling bout and still found changes in physiological measures ($\dot{V}O_2$, HR) subsequent to a whole-body HST with comparable intensities to the current study (6 exercises, 3x12 at 70%-1RM). They found significantly less effect on the same physiological variables with volume-equated strength training at a lower intensity (6 exercises, 3x12 at 50%-1RM). The authors suggested, that intensity-induced fatigue, which leads to additional recruitment of motor units and muscle fibres, might be responsible for these differences. Drummond et al. (13) supported this idea and assumed depletion of glycogen stores, due to the resistance training, could lead to reduced performance in the subsequent endurance bout. However, our study examined well-trained athletes, who were used to CT, in contrast to less trained or even sedentary individuals in the aforementioned studies. The regular endurance training of the kayakers likely made them more resistant to muscle glycogen depletion. Long-term endurance training is known to induce increases in mitochondrial protein content and increased capillary substrate supply which results in a greater reliance on fat oxidation in the trained muscle and concomitantly a reduced oxidation of glycogen for energy production (28). Additionally, muscle glycogen content is increased in the trained muscle (24,48). Consequently, it seems that the subsequent endurance performance in the current study wasn't negatively affected as prior HST didn't deplete glycogen stores to an extend that would have influenced muscle force production and finally altered endurance performance variables. Therefore, it is suggested that training history and performance level of the athletes have an impact on the occurrence and amount of effect a HST has on subsequent aerobic endurance exercise. However, as already discussed above, we did not examine the reverse exercise order. It is possible that an aerobic endurance session would likewise have no detrimental impact on a subsequent HST session in well-trained athletes, who are used to CT. Further investigations are needed for clarification.

A further finding of the present study is the significant difference of RER values between the E and SE condition (Figure 2), with increased fat utilization for the endurance bout subsequent to HST. This finding is in accordance with previous studies (29, 45). Kang et al. (31) promoted that the increases in fat utilization seems to be caused by an increased lipolysis following strength training. The authors further explained that right after finishing an intense exercise session glycerol and free fatty acid concentrations rapidly rise during the recovery and this leads to imbalances with regard to supply and demand of these substrates. This rise is a result of an increased growth-hormone release after resistance exercise, which is an important stimuli for fat metabolism (25). Furthermore, Randle et al. (40) found that the availability of fatty acids suppresses the glucose oxidation, which explains the decreased reliance on carbohydrates for energy supply in the SE condition, visible by the lower RER. Aerobic ET generally aims to improve the bodies' utilization of fat for energy supply, as this is the most economical way to provide the musculature with energy. Sequencing ST prior to ET could lead to superior adaptations in aerobic endurance performance, because the increased utilization of fat as an energy substrate throughout an aerobic endurance bout could probably facilitate the desired adaptations. However, long-term investigations are needed to confirm this theory. Furthermore, considering that a prior exercise bout leads to lower RER during subsequent exercise, it is speculated that aerobic ET conducted prior HST impairs muscle growth in the long term. This may be because the aerobic ET leads to depletion of muscle glycogen stores, which subsequently decreases the muscles ability to work anaerobically (50). Research suggests, that training regimes that result in accumulation of metabolites originated from anaerobic energy metabolism lead to greater increases in muscle growth compared to regimes where less metabolite build up occurs (45). As a conclusion, ET probably could impair the long-term effects of subsequent HST with regard to gains in muscle mass.

Regarding $\dot{V}O_2$ kinetics following exercise, research suggests that prior heavy intensity endurance exercise leads to more rapid overall $\dot{V}O_2$ response as a result of faster $\dot{V}O_2$ increments at the onset of exercise. This is called a priming effect. It is suggested that different mechanisms are responsible for this effect. Increased availability of muscle O_2, elevated muscle oxidative enzyme activity, enhanced carbon substrates supply and altered motor recruitment profiles seem to promote the speeded $\dot{V}O_2$ kinetics (4). Acidosis from prior exercise stimulates O_2 availability by facilitating vasodilatation and this in turn might support faster $\dot{V}O_2$ response (23). Faster $\dot{V}O_2$ kinetics following exercise would implement a faster and enhanced reliance on fat metabolism for energy supply during a subsequent endurance bout, which would save muscle glycogen and probably improve endurance performance. Unfortunately, as we did not measured baseline $\dot{V}O_2$-values prior the endurance exercise, we were not able to calculate and compare primary $\dot{V}O_2$ response for both conditions. However, the significantly decreased RER values in the first time interval of the SE condition compared to the E condition and the second time interval within the same condition support this idea. Nonetheless, further investigations on the immediate $\dot{V}O_2$ kinetics at the beginning of endurance exercise subsequent to a HST are needed to confirm whether HST might have a similar priming effect as heavy intensity endurance exercise has.

Besides the common physiological endurance performance measures we investigated two different types of exercise economy in our study. ECO expresses exercise economy as oxygen cost per distance and is closely related to $\dot{V}O_2$ values during exercise (39). Therefore it isn't quite surprising that no differences between conditions for ECO were observed, as $\dot{V}O_2$ did not reveal any between-condition changes as well. These data highlight, that the athletes were not required to increase their oxygen consumption post the HST to exercise at the same relative velocity of $\dot{V}O_{2max}$ compared to the E condition, although the increased lactate and RPE values let assume that muscular fatigue was induced to some extend. A reason for this might be that the facilitated fat metabolism, seen through the decreased RER, optimised the muscles energy metabolism to an extend that made any further physiological adjustment for fatigue compensation unnecessary. In contrast to ECO, CUC expresses economy as a unit of energy expenditure expressed in calories during exercise and is believed to be a more sensitive analysis of exercise economy (16). As the energy yielded per liter of oxygen is dependent on the substrate metabolized, changes in economy based on CUC can occur, although no changes in $\dot{V}O_2$ are apparent. However, even CUC values did not highlight any significant differences between the examined conditions. Thus, we have to assume, that although HST induced some extend of fatigue, muscle force production during endurance paddling was not influenced to an extend that required more energy compared to the rested condition.

A possible reason for that might be post activation potentiation (PAP) effects. According to Sale (43) ST induces increases in force output in single motor units which leads to decreased motor unit firing rates during continuous submaximal contractions. As a result, the number of nerve impulses and muscle action potentials per time are reduced. This may lead to more economical force production and finally to decreased energy demands per muscle contraction. A decreased energy demand per muscle contraction could then be the reason why no significant changes between conditions in CUC occurred, although RER significantly differed. Thus, obviously fatigue and improved force production can coexist in skeletal muscle (5). This is supported by a study on kayakers, who demonstrated improved 500m-time-trial performance after high intensity contractions within their warm-up, which were related to higher peak power outputs per stroke (6). However, whether resistance training leads to improvements in performance depends on the balancing of muscular fatigue and the muscle potentiation (41). The rest time following a ST to allow for enough recovery to benefit from PAP effects seems to be quite individual and lies within a time frame of about 5 to 20 minutes or even above (5). Regarding this, it is absolutely possible, that the athletes in the present study benefitted from PAP effects subsequent to the HST and therefore didn't reveal any differences in biomechanical and physiological measures between the conditions, despite the changes in substrate utilization. In turn, the above mentioned studies that highlighted changes in different physiological and decreases in performance, probably did not start the endurance exercise within the individual time frame that would have allowed to utilize PAP effects for endurance performance. However, this remains highly speculative and further investigations on possible PAP effects of ST onto subsequent aerobic endurance performance in kayakers are needed to prove this hypothesis. Additionally, RER data, as well as the CUC data, which have been calculated from RER, need to be interpreted with caution. RER generally is used to determine the relative contribution of glycogen and fat as energy sources to the overall energy expenditure. Dietary intake has been found to influence muscle glycogen content and circulating substrates in athletes, which in consequence, may be able to alter substrate utilisation in athletes during steady-state exercise (26). As we did not take a food diary for every athlete the days prior and at the day of investigations, it may be possible that dietary intake may have influenced the outcomes to some extend.

Considering the importance of recovery for athletes, the rapid decrease of elevated blood lactate concentrations during the first 10-minute interval of the endurance bout in the SE condition is another interesting finding. Lactate values prior the endurance bout were significantly elevated in the SE condition compared to the E condition (table 5), but this difference was not apparent in the first interval anymore. Although we have no comparable data for lactate progression without any exercise subsequent to the HST, the endurance exercise seems to have facilitated the removal of anaerobic metabolites. This is in agreement with Bompa and Haff (8), who promote active recovery as a highly efficient recovery tool for athletes, which is even more effective than passive recovery strategies. They link active recovery with increased lactate clearance, dampening of the central nervous system activity and reduction in exercise-induced muscle soreness. However, they note that these effects were mainly found during intensities below 50% of $\dot{V}O_{2max}$, which is less than the intensity performed in the present investigation. The well-trained status of our subjects probably enabled them to recover even at higher intensities. Considering that kayakers perform multiple endurance and strength session per day for about 6 to 7 days in a week, leading to persistent accumulation of fatigue, performing aerobic endurance sessions post ST sessions could be beneficial not only with regard to strength development, but also for overall recovery and fitness-status. However, as already stated above, anaerobic metabolite accumulation is considered to be a possible trigger for muscular hypertrophy (45). Thus, the removal of lactate may impair the long-term muscle building processes.

With regard to the performance level of our participants, results of the incremental test revealed comparable $\dot{V}O_{2max}$ data with a previous study (present study: 44.4 ±4.6 mL/min/kg; Forbes et al.: 44.9 ±9.8 mL/min/kg) on age-related kayakers by Forbes et al. (17). In the current study all but one participant were females. When comparing our participants with a study by Bishop (6) who reported mean relative $\dot{V}O_{2peak}$ of 44.8 ±6 mL/min/kg in older (23 ±5 years) female kayakers with international performance levels, the endurance capacity seems to be on a high-level. No comparable data for age related groups of kayakers regarding strength abilities in the implemented exercises exist. Considering that most of the participants have won medals at the German national championships, general performance level can be rated as quite high. Conclusively, we can confirm that our study reached the aim to be able to examine the acute effects of the implemented CT sequence in well-trained kayakers. Thus, our findings should be highly useful for practical application in well- to highly-trained kayak athletes.

When analysing the results several limitations of the present investigation have to be considered. First of all, we only examined the effects of a HST on a LSDT but not the reverse order. Thus, it remains unclear whether the reverse order really has a detrimental effect on the strength training in this special population. With regard to the small sample size the probability of a type-2 error is relatively high. Furthermore, all but one participant were females and it is not clear whether gender could have an impact on the outcomes or not. Additionally, as stated before, outcomes RER and CUC have been interpreted with caution, as no food diary has been taken and macronutrient intake may have altered the substrate utilization during exercise. Most importantly, one has to consider that we only examined acute effects of CT during a single exercise session. Care has to be taken when considering the long-term effects, as simply translating the acute effects to chronic adaptations may not be appropriate. Conclusively, further investigations on the long-term effects of sequencing strength training prior endurance training are crucial to make recommendations for the concurrently training athlete.

The uniqueness in being the first to examine the acute effects of CT in well-trained kayakers is a definite strength of our investigation. To the best of the authors' knowledge, till today no study examined the acute interference effects in the upper body using both upper body strength and endurance exercises and therefore our findings can be highly useful for coaches who work with upper-body dominant sports. Furthermore, considering that the body of well-trained athletes, who are used to CT, is adapted to this type of training, it possibly evokes different effects and adaptations compared to the untrained and sedentary individual. As almost all studies on the acute effects of CT examined untrained individuals, the present study can be of high value for coaches working with well-trained individuals. Another strength of the current study is that we examined a training sequence that replicates common training modalities in the sport of sprint kayaking and therefore the results are highly applicable to real training conditions.

5 PRACTICAL APPLICATIONS

The results of the present study suggest that HST does not negatively influence a subsequent steady-state aerobic endurance bout in well-trained kayakers. The results tend to support recommendations for the optimization of CT by García-Pallarés et al. (21) that ST should be sequenced prior endurance sessions when training concurrently for strength and endurance. Our results suggest that aerobic endurance performance subsequent to ST is characterized by higher fat oxidation rates for energy supply. Additionally, it is possible that ST leads to PAP effects during the endurance bout, which are characterized by a more economical force generation and lead to less energy demands per time unit. As aerobic ET aims to improve fat oxidation rates during exercise and to economise force generation during repetitive submaximal contractions, sequencing HST prior the ET may lead to improved endurance adaptations. Considerably more, our findings suppose that aerobic exercise following HST facilitates recovery from the ST and thus this sequence possibly reduces accumulation of fatigue. These information are highly useful for kayak coaches, as well as strength and conditioning coaches who are working with high performance kayakers and looking to improve the simultaneous training of strength and endurance performance.

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7 APPENDICES

7.1 Ethics Application Forms

St Mary's University

Ethics Sub-Committee

Application for Ethical Approval (Research)

This form must be completed by any undergraduate or postgraduate student, or member of staff at St Mary's University, who is undertaking research involving contact with, or observation of, human participants.

Undergraduate and postgraduate students should have the form signed by their supervisor, and forwarded to the School Ethics Sub-Committee representative. Staff applications should be forwarded directly to the School Ethics Sub-Committee representative. All supporting documents should be merged into one PDF (in order of the checklist) and clearly entitled with your **Full Name, School, Supervisor.**

Please note that for all undergraduate research projects the supervisor is considered to be the Principal Investigator for the study.

If the proposal has been submitted for approval to an external, properly constituted ethics committee (e.g. NHS Ethics), then please submit a copy of the application and approval letter to the Secretary of the Ethics Sub-Committee. Please note that you will also be required to complete the St Mary's Application for Ethical Approval.

Before completing this form:

- Please refer to the **University's Ethical Guidelines**. As the researcher/ supervisor, you are responsible for exercising appropriate professional judgment in this review.
- Please refer to the Ethical Application System (Three Tiers) information sheet.
- Please refer to the Frequently Asked Questions and Commonly Made Mistakes sheet.
- If you are conducting research with children or young people, please ensure that you read the **Guidelines for Conducting Research with Children or Young People**, and answer the below questions with reference to the guidelines.

Please note:

In line with University Academic Regulations the signed completed Ethics Form must be included as an appendix to the final research project.

If you have any queries when completing this document, please consult your supervisor (for students) or School Ethics Sub-Committee representative (for staff).

St Mary's University Twickenham London

St Mary's Ethics Application Checklist

The checklist below will help you to ensure that all the supporting documents are submitted with your ethics application form. The supporting documents are necessary for the Ethics Sub-Committee to be able to review and approve your application.

Please note, if the appropriate documents are not submitted with the application form then the application will be returned directly to the applicant and may need to be re-submitted at a later date.

	Enclosed? (delete as appropriate)		Version No
Document	Yes	Not applicable	
1.Application Form	Mandatory		
2.Risk Assessment Form	x		
3.Participant Invitation Letter	x		
4.Participant Information Sheet	Mandatory		
5.Participant Consent Form	Mandatory		
6.Parental Consent Form	x		
7.Participant Recruitment Material - e.g. copies of Posters, newspaper adverts, website, emails			
8.Letter from host organisation (granting permission to conduct the study on the premises)			
9. Research instrument, e.g. validated questionnaire, survey, interview schedule	x		
10.DBS included	x		

11.Other Research Ethics Committee application (e.g. NHS REC form)	x		

I can confirm that all relevant documents are included in order of the list and in one PDF document entitled with you: ***Full Name, School, Supervisor.***

Signature of Applicant: Manuel Matzka

Signature of Supervisor:

Ethics Application Form

1) Name of proposer(s)	Manuel Matzka
2) St Mary's email address	135081@live.stmarys.ac.uk
3) Name of supervisor	Dr Stephen Patterson

4) Title of project	Acute effects of a hypertrophy strength training session on a subsequent steady-state endurance bout in well-trained youth kayakers

5) School or service	School of Sport, Health & Applied Science
6) Programme (if undergraduate, postgraduate taught or postgraduate research)	Ms Strength and Conditioning
7) Type of activity/research (staff / undergraduate student research / postgraduate student)	Postgraduate Student

8) Confidentiality	
Will all information remain confidential in line with the Data Protection Act 1998	YES

9) Consent	
Will written informed consent be obtained from all participants / participants' representatives?	YES

10) Pre-approved protocol	
Has the protocol been approved by the Ethics Sub-Committee under a generic application?	NO Date of approval:

11) Approval from another Ethics Committee	
a) Will the research require approval by an ethics committee external to St Mary's University?	NO
b) Are you working with persons under 18 years of age or vulnerable adults?	YES

12) Identifiable risks	
a) Is there significant potential for physical or psychological discomfort, harm, stress or burden to participants?	NO
b) Are participants over 65 years of age?	NO
c) Do participants have limited ability to give voluntary consent? This could include cognitively impaired persons, prisoners, persons with a chronic physical or mental condition, or those who live in or are connected to an institutional environment.	NO
d) Are any invasive techniques involved? And/or the collection of body fluids or tissue?	YES
e) Is an extensive degree of exercise or physical exertion involved?	YES
f) Is there manipulation of cognitive or affective human responses which could cause stress or anxiety?	NO
g) Are drugs or other substances (including liquid and food additives) to be administered?	NO
h) Will deception of participants be used in a way which might cause distress, or might reasonably affect their willingness to participate in the research? For example, misleading participants on the purpose of the research, by giving them false information.	NO
i) Will highly personal, intimate or other private and confidential information be sought? For example sexual preferences.	NO
j) Will payment be made to participants? This can include costs for expenses or time.	NO If yes, please provide details
k) Could the relationship between the researcher/ supervisor and the participant be such that a participant might feel pressurised to take part?	NO

13) Proposed start and completion date
Please indicate: • When the study is due to commence. • Timetable for data collection. • The expected date of completion. Please ensure that your start date is at least 3 weeks after the submission deadline for the Ethics Sub-Committee

meeting.
Start Date: 10th January 2016 Completion Date: 29th February 2016

14) Sponsors/Collaborators
Please give names and details of sponsors or collaborators on the project. This does not include you supervisor(s) or St Mary's University. • Sponsor: An individual or organisation who provides financial resources or some other support for a project. • Collaborator: An individual or organisation who works on the project as a recognised contributor by providing advice, data or another form of support.
Collaborator: Prof. Dr. Holger Krakowski-Roosen (University of Applied Science Hamm-Lippstadt)

15. Other Research Ethics Committee Approval
• Please indicate whether additional approval is required or has already been obtained (e.g. the NHS Research Ethics Committee). • Please also note which code of practice / professional body you have consulted for your project • Whether approval has previously been given for any element of this research by the University Ethics Sub-Committee.
No additional approval required

16. Purpose of the study
In lay language, please provide a brief introduction to the background and rationale for your study. • Be clear about the concepts / factors / performances you will measure / assess/ observe and (if applicable), the context within which this will be done. • Please state if there are likely to be any direct benefits, e.g. to participants, other groups or organisations.
In order to be a successful kayaker, it requires a mixture of aerobic fitness and maximum strength capabilities. Elite kayakers regularly use both aerobic endurance training and strength training as part of their daily training plan in order to help improve performance. However the order in which this training is performed may impact the next training session, for example performing strength training before an aerobic bout of exercise may reduce performance due to fatigue associated with the strength training bout. The aim of the study is to examine whether upper body strength training acutely influences endurance performance paramters during a subsequent low-intensity endurance exercise bout on a kayak ergometer. This is the first study to examine this realtionship in upper body exercise. Previous research on lower body exercise is equivocal and evidence for clear recommendations are lacking. Participants will benefit by the individual analysis of their endurance performance. Sports which rely on both

strength and endurance performance and especially the sport of kayaking will benefit from the study results by getting an insight into the acute influences strength training has on low intensity endurance performance.

17. Study Design/Methodology
In lay language, please provide details of: a) The design of the study (qualitative/quantitative questionnaires etc.) b) The proposed methods of data collection (what you will do, how you will do this and the nature of tests). c) You should also include details regarding the requirement of the participant i.e. the extent of their commitment and the length of time they will be required to attend testing. d) Please include details of where the testing will take place. e) Please state whether the materials/procedures you are using are original, or the intellectual property of a third party. If the materials/procedures are original, please describe any pre-testing you have done or will do to ensure that they are effective.
The study is a quantitative experiment. The study will utilize a randomized crossover design with individuals recruited performing both experimental conditions. Participants are required to visit the laboratory on four separate occasions. Sessions 1: This will consist of anthropometric measures and maximum strength testing. This session will last approximately 60 minutes. Sessions 2: On this occasion participants will perform an incremental test on a kayak ergometer to exhaustion. During this time online measures of gas analysis will be performed for determination of maximal oxygen uptake. This will allow for determination of the intensity (55% VO2 max) during the experimental condition. This session will last approximately 60 minutes. Sessions 3 & 4: On these occasions participants will perform the experimental conditions in a randomized, crossover fashion. On one occasion participants will perform the endurance exercise only and on the other occasion participants will perform strength training before the endurance exercise bout. A standardized warm-up protocol, consisting of 5 minutes paddling on the kayak ergometer at a speed of 8 km/h followed by 5 minutes of dynamic upper-body movements precedes both sequences. The strength training will consist of the following exercises; Bench Pull, Bench Press, Latissimus Pulldown and Shoulder Press. Each exercise is performed for eight to ten repetitions at an intensity of 70% of their volitional one repetition maximum. The endurance exercise willl be conducted on a kayak ergometer for duration of 40 minutes at an speed / intensity of 55% of maximal oxygen consumption. Measures of breathing, including, oxygen and carbon dioxide will be assessed via an online gas. Capillary blood lactate samples will be taken from the earlobe at rest, at 10, 20, 30 minutes during the exercise bout and as well 0 and 5 minutes post exercise. There will be 20 minutes of rest separating the strength and endurance bout of exercise. These sessions will last approximately 120 minutes. All testing will take place in a laboratory of the University of Applied Science Hamm-Lippstadt, Germany.

18. Participants

Please mention: a) The number of participants you are recruiting and why. For example, because of their specific age or sex. b) How they will be recruited and chosen. c) The inclusion / exclusion criteria's. d) For internet studies please clarify how you will verify the age of the participants. e) If the research is taking place in a school or organisation then please include their written agreement for the research to be undertaken.
The number of participants that will be recruited will be between 10 and 18. This is mainly due to the fact that this study recruits only well-trained elite kayakers in an age range of 15 to 25 years with at least four years of kayaking experience. Usual training frequency has to be six days per week with an average training volume of at least eight hours per week. Subjects are recruited from local performance base camps in western Germany. Using Lehr's (1992) formula ($N = 16s^2 \cdot d^{-2}$), the appropriate number of participants would be eight for a statistical power of 0.8 with a 0.05 alpha level.

19. Consent
If you have any exclusion criteria, please ensure that your Consent Form and Participant Information Sheet clearly makes participants aware that their data may or may not be used. a) Are there any incentives/pressures which may make it difficult for participants to refuse to take part? If so, explain and clarify why this needs to be done b) Will any of the participants be from any of the following groups? ➢ Children under 18 ➢ Participants with learning disabilities ➢ Participants suffering from dementia ➢ Other vulnerable groups. c) If any of the above apply, does the researcher/investigator hold a current DBS certificate? A copy of the DBS must be included with the application. d) How will consent be obtained? This includes consent from all necessary persons i.e. participants and parents.
A). No B). Yes. Some of the participants in the elite training centres will be under the age of 18. C). Yes D). All participants will provide written consent before being able to take part in the study. Participants that are under 18 years of age will need a signed consent from their legal guardian. German version of DBS is added to the

application.

20. Risks and benefits of research/ activity
a) Are there any potential risks or adverse effects (e.g. injury, pain, discomfort, distress, changes to lifestyle) associated with this study? If so please provide details, including information on how these will be minimised. b) Please explain where the risks / effects may arise from (and why), so that it is clear why the risks / effects will be difficult to completely eliminate or minimise. c) Does the study involve any invasive procedures? If so, please confirm that the researchers or collaborators have appropriate training and are competent to deliver these procedures. Please note that invasive procedures also include the use of deceptive procedures in order to obtain information. d) Will individual/group interviews/questionnaires include anything that may be sensitive or upsetting? If so, please clarify why this information is necessary (and if applicable, any prior use of the questionnaire/interview). e) Please describe how you would deal with any adverse reactions participants might experience. Discuss any adverse reaction that might occur and the actions that will be taken in response by you, your supervisor or some third party (explain why a third party is being used for this purpose). f) Are there any benefits to the participant or for the organisation taking part in the research (e.g. gain knowledge of their fitness)?
A). This study involves an exercise tests which require participants to exercise until exhaustion. Participants will be fully familiarised to the protocol before exercising. This is exercise and training that they perform regularly as part of their daily training. Inclusion criteria will ensure participants are injury free for 3 months and use of standardised warm-up will ensure reduced chance of injury. A Physical Activity Readiness Questionnaire (PAR-Q) will be used to further minimise risk. B). There is very minor risk from the associated protocol. The use of highly trained participants will annul the potential risks from procedures required to complete the study. Prior training and familiarisation will help minimise risk to participants. C). Blood samples will be taken during all visits for participants to measure blood lactate. Blood samples will be taken at the earlobe using heparinised and calibrated capillary. Location chosen as earlobe is less painful die to fewer nerve endings. The experimenter will wear gloves at all times when collecting blood samples. The experimenter has had that training as part of STM04 Physiology of training module. Blood samples will be taken in accordance with SHAS guidelines.

D). No

E). If a need for medical attention, knowledge of nearest first aid, first aider will be sought. Adverse situations will be dealt with efficiently and in a calm / professional manner. If moments of discomfort arise, participants will be reminded that they are able to withdraw from study without a need to provide reason.

F). Each participant gets detailed information about their endurance capabilities based on the data from the incremental test on the kayak ergometer. Additionally current status of strength abilities in the prime exercises for kayaking is provided. Therefore the subjects receive helpful data for further training and goal setting. Additionally each participant will individually be informed about the acute effect of strength training on their endurance training performance. This data can be utilized to individually improve sequencing of strength and endurance sessions

21. Confidentiality, privacy and data protection

a) What steps will be taken to ensure participant's confidentiality?
- Describe how data, particularly personal information, will be stored.
- Consider how you will identify participants who request their data be withdrawn, such that you can still maintain the confidentiality of theirs and others data.

b) Describe how you manage data using a data a management plan.
- You should show how you plan to store the data securely and select the data that will be made publically available once the project has ended.
- You should also show how you will take account of the relevant legislation including that relating data protection, freedom of information and intellectual property.

c) Who will have access to the data? Please identify all persons who will have access to the data (normally yourself and your supervisor).

d) Will the data results include information which may identify people or places?
- Explain what information will be identifiable.
- Whether the persons or places (e.g. organisations) are aware of this.
- Consent forms should state what information will be identifiable and any likely outputs which will use the information e.g. dissertations, theses and any future publications/presentations.

A) All data will be held in the strictest confidence and no participant information will be discussed outside of the research group. Participant information is stored and archived entirely anonym. Every participant will get an identification number and all data is archived to this number. Personal data, consent form and study results will be individually filed for each subject. At any time subjects have the right to persist on the deletion of their data.

B) All data will be held in a locked room and cabinet and/or held on a password protected computer. Data dissemination will be done in strict anonymity

C) The principal investigator and other selected investigators D) No individuals will be identified, however St Mary's will be identifiable from any scientific communications to the wider community

22. Feedback to participants
Please give details of how feedback will be given to participants: • As a minimum, it would normally be expected for feedback to be offered to participants in an acceptable to format, e.g. a summary of findings appropriate written. • Please state whether you intend to provide feedback to any other individual(s) or organisation(s) and what form this would take.
If requested, each participant gets all mesaured data and performance outcomes of this study with additional feedback and analysis of the data in written and structured format. No other individual(s) or organisation(s) are intended to receive any data or informations from the individuals.

The proposer recognises their responsibility in carrying out the project in accordance with the University's Ethical Guidelines and will ensure that any person(s) assisting in the research/ teaching are also bound by these. The Ethics Sub-Committee must be notified of, and approve, any deviation from the information provided on this form.

Signature of Proposer(s)	Date: 03.11.15
Signature of Supervisor (for student research projects)	Date:3.11.15

Approval Sheet

Name of applicant: Manuel Matzka Name of supervisor: Stephen Patterson Programme of study: MSc. Strength and Conditioning Title of project: Acute effects of strength training on physiological and specific endurance parameters in well-trained kayakers prior to a low-intensity aerobic endurance bout on a kayak ergometer.

Supervisors, please complete section 1 or 2. If approved at level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

SECTION 1 Approved at Level 1 Signature of supervisor (for student applications).. Date...
SECTION 2 Refer to School Ethics Representative for consideration at Level 2 or Level 3 Signature of supervisor.. Date...

SECTION 3 To be completed by School Ethics Representative Approved at Level 2 Signature of School Ethics Representative.. Date..
SECTION 4 To be completed by School Ethics Representative. Level 3 consideration required byt the Ethics Sub-Committee (including all staff research involving human participants) Signature of School Ethics Representative.. Date.. Level 3 approval – confirmation will be via correspondence from the Ethics Sub-Committee

7.2 Ethics Approval

St Mary's University Twickenham London

cc Stephen Patterson

Manuel Matzka (SHAS) ''Acute effects of strength training on physiological and specific endurance parameters in well-trained kayakers prior to a low-intensity aerobic endurance bout on a kayak ergometer''

7 January 2016

Dear Manuel

University Ethics Sub-Committee

Thank you for re-submitting your ethics application for consideration.

I can confirm that all required amendments have been made and that you therefore have ethical approval to undertake your research.

Yours sincerely

Dr Conor Gissane
Chair of the Ethics Sub-Committee

7.3 Participant Information Sheet

Acute effects of a hypertrophy strength training session on a subsequent steady-state endurance bout in well-trained youth kayakers

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this:

What is the purpose and aim of our research?

The purpose of the study is to examine if a strength-training bout acutely influences physiological and task-specific performance parameters in a subsequent low-intensity endurance bout in well-trained kayakers. Getting a more in depth understanding about how sequencing of training acutely influences concurrent training of strength and endurance helps coaches and athletes to improve daily training responses and long-term training effects.

Invitation to participate

You are invited to participate in a research project examining the effect of an acute bout of strength training on endurance performance.

Who is organising the research?

The research is being organised by Mr Manuel Matzka (MSc Student). Other investigators include Mr Matzka's research supervisor, Dr Stephen Patterson.

What will happen to the results of the study?

The results of the research will be available from Mr Matzka within 60 days of all data being collected. You will receive your own individual results. Ultimately your data may be published in international journals but it will not be possible to identify you from these publications. If you would like to be sent a copy of the work when it is published we can arrange this.

Source of funding for the research

There are no external sources of funding for this study.

Contact for further information

Mr Manuel Matzka – 135081@live.stmarys.ac.uk

Dr Stephen Patterson – Stephen.Patterson@stmarys.ac.uk

Why you have been invited to take part

You have been chosen because you are a well-trained kayaker with at least four years of kayaking experience and a weekly average of 8 hours of concurrent kayak and strength training in the past year.. We plan to carry out this study on 10-18 people like you.

Do I have to take part?

It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. You will be given copies of these.

Can I withdraw from the study?

If you decide to take part you are still free to withdraw at any time, without giving a reason and without any penalty.

What will happen if you agree to take part?

There will be four separate study days, occurring 3-7 days apart. You will be asked to refrain from caffeine and alcohol for 24 hours prior to each study. We will also ask you to avoid any strenuous exercise at all for 24 hours prior to the study. You will be asked to come to the Laboratory where you will be asked some simple health questions and then be asked to sign a consent form.

Day 1 – Anthropometric and Strength Testing

You will arrive at the laboratory and fill in a health questionnaire and sign and informed consent form. You will then have anthropometric measures taken, which include body-height, bodyweight and body composition using bioelectrical impedance analysis.

You will then perform a standardised warm up followed by a familiarisation of the strength training movements. You will then perform a 1 repetition maximum test for the following exercises: Bench Pull, Bench Press, Shoulder Press, Latissimus Pulldown. This session will last approximately 60 minutes

Day 2 – Incremental Kayak Test

You will arrive at the laboratory and complete an incremental test to exhaustion on a kayak ergometer. This will involve starting at 9 km/h and will increase by 0,5 km/h every minute until exhaustion. During this time you will be fitted with a gas mask and breath-by-breath gas exchange will be collected throughout.

Day's 3 & 4 – Intervention Trials

On these occasions participants will perform the experimental conditions in a randomized, crossover fashion. On one occasion participants will perform the endurance exercise only and on the other occasion participants will perform strength training before the endurance exercise bout. A standardized warm-up protocol consisting of 5 minutes paddling on the kayak ergometer at a speed of 8 km/h followed by 5 minutes of dynamic upper-body movements precedes both sequences. The strength training will consist of the following exercises; Bench Pull, Bench Press, Latissimus Pulldown and Shoulder Press. Each exercise is performed for eight to ten repetitions at an intensity of 70% of their volitional one repetition maximum. The endurance exercise will be conducted on a kayak ergometer for duration of 40 minutes at the speed / intensity of 55% of maximal oxygen consumption. Measures of breathing, including, oxygen and carbon dioxide will be assessed via an online gas. Capillary blood lactate samples will be taken from the earlobe at rest, at 10, 20, 30 minutes during the exercise bout and as well 0 and 5 minutes post exercise. There will be 20 minutes of rest separating the strength and endurance bout of exercise. These sessions will last approximately 120 minutes.

Are there any risks or side effects?

Although it is unlikely, testing and experimental sessions include the risk of musculoskeletal injuries or cardiovascular problems. Proper warm-up and preparation for the following task will minimize the risks. To further reduce these risks you should only participate if you have been free of any injury or health disorder for the past three months. In the unlikely event of an injury or cardiovascular problem, experimental sessions are cancelled immediately and any necessary treatment will be implemented immediately.

Agreement to participate in this research should not compromise your legal rights if something goes wrong

Research can carry unforeseen risks and we want you to be informed of your rights in the unlikely event that any harm should occur as a result of taking part in this study. Every care will be taken to ensure that your well-being and safety are not compromised during the course of the study. St Marys University also has insurance arrangements in place in the unlikely event that something does go wrong and you are harmed as a result of taking part in the research study.

Are there any special precautions you must take before, during or after taking part in the study?

You will be asked to refrain from caffeine and alcohol for 24 hours prior to each study. We will also ask you to avoid any strenuous exercise at all for 24 hours prior to the study.

What will happen to any information/data/samples that are collected from you?

Only the researchers and a representative of the Research Ethics Committee will have access to the data collected during the study. However, your identity will not be revealed. All information which is collected about you during the course of the research will be kept strictly confidential. We will keep a record that you have taken part in the study but will not keep any other personal information about you. Professional standards of confidentiality will be adhered and the handling, processing, storage and destruction of data will be conducted in accordance with the Data Protection Act (1998).

Are there any benefits from taking part?

There will be no direct benefits from the study. However all results of the pre-tests and the experimental sessions are provided to you. Additionally, if requested, you get a detailed analysis of your data, which provide you with useful data for your further training.

How much time will I need to give up to take part in the project?

The total time commitment will be approx. 6 hours over 4 weeks spread over 4 visits.

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP TOGETHER WITH A COPY OF YOUR CONSENT FORM

7.4 Participant Consent Form

Name of Participant: ______________________________

Title of the project: **Acute effects of a hypertrophy strength training session on a subsequent steady-state endurance bout in well-trained youth kayakers**

Main investigator: Manuel Matzka
Email: 135081@live.stmarys.ac.uk

Members of the research team: Dr Stephen Patterson – Stephen.patterson@stmarys.ac.uk

1. I agree to take part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I provide will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant (print)…………………………Signed………………….Date……………

Name of witness (print)……………………………..Signed………………….Date……………

If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.

Title of Project: Acute effects of strength training on physiological and specific endurance parameters in well-trained kayakers prior to a low-intensity aerobic endurance bout on a kayak ergometer.

I WISH TO WITHDRAW FROM THIS STUDY

Name: ______________________________

Signed: ___________________________ Date: ________________

7.5 Parental Consent Form

Name of parent: ____

Name of participating child: _____________________________________

Title of the project: **Acute effects of a hypertrophy strength training session on a subsequent steady-state endurance bout in well-trained youth kayakers**

Main investigator: Manuel Matzka
Email: 135081@live.stmarys.ac.uk

Please confirm below that you agree with the following statements:

1. I agree my child to take part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what the role of my child will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that my child is free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information my child provides will be safeguarded.
4. My child and I are free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which my child has supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of parent (print)………………………………Signed………………….Date…………….

Name of witness (print)……………………………..Signed………………….Date…………….

7.6 Letter of Collaboration

Der Präsident

HOCHSCHULE
HAMM-LIPPSTADT
University of Applied Sciences

Hochschule Hamm-Lippstadt, Marker Allee 76-78, 59063 Hamm

To
St Mary's University
Waldegrave Road
Twickenham TW1 4SX

Hamm, den 24.07.16

Prof. Dr. Holger Krakowski-Roosen
Angewandte Sportwissenschaften
Applied Sport Sciences

+49 (171) 67 2222 1
+49 (23 81) 87 89 - 510
holger.krakowski-roosen@hshl.de

Postanschrift:
Marker Allee 76-78
59063 Hamm

Mein Zeichen:
HKR

Ihr Zeichen:

Letter of Collaboration

To whom it may concern,

With this letter I confirm my collaboration with your master student Mr Manuel Matzka regarding the research project he is conducting to obtain his master degree in "Strength and Conditioning". I provide Mr Matzka with the needed equipment for his research project, as well as with my knowledge and experiences about the proper and safe execution of investigations with humans. If you have any further questions regarding myself, please feel free to contact me. You can find my contact information on this letter.

Yours sincerely,

Prof. Dr. Holger Krakowski-Roosen

Privatadresse:
Leinsamenweg 80
50933 Köln